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Reactor Assessment and Prognosis Tool for Nuclear Power Plants and Its Application Strategies – a Perspective

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1. INTRODUCTION

During a severe nuclear or radiological emergency, there is a need for information about the status of event and its safety significance. Although realistic, comprehensive and timely information are crucial for successful emergency response, it is a very challenging task during accident conditions. When a severe accident is encountered, however, the available safety parameter information is often limited to diagnose and predict the relevant plant states. Even for such a situation, the main control room (MCR) operators and technical support centre (TSC) staff need to take quick actions to prevent further accident progression. If the plan information is unknown in advance, MCR operators and TSC staff could not cope more effectively with future accident progressions. As result, a diagnostic capability for plant states can prevent and mitigate the current state of the plant in such a way to estimate progression of plant states. Moreover, the prognostic capability for an anticipated accident progression should be also considerate to provide the MCR operator or TSC staff enough time to take actions for mitigating the consequences of the accident conditions.

In this regard, the International Atomic Energy Agency (IAEA), Institute of Radiation Protection and Nuclear Safety (IRSN) in France, the Canadian Nuclear Safety Commission (CNSC) in Canada have developed the Reactor Assessment Tools (RATs) for evaluating operability of critical safety functions during a nuclear emergency. The RAT has been in use for performing a rapid situational evaluation with limited information available during an emergency.

In Korea, KINS has developed the Atomic Computerized technical Advisory system for the Radiological Emergency (AtomCARE) to diagnose and prognosis the reactor and plant state in case of nuclear emergency. To enhance further the existing capability, it should be considered to link diagnosis and prognosis tools with AtomCARE in order to provide technical support for MCR operators and TSC staff in case of nuclear emergency.

Hence, the purpose of this paper is to share the concepts of the RATs developed by IAEA, IRSN and CNSC and to suggest how to enhance capability of diagnosis and prognosis for AtomCARE during an emergency at a nuclear power plant.

2. STATUS OF RAT DEVELOPMENTS

2.1 IAEA

The IAEA has developed a Reactor Assessment Tool (RAT) to evaluate critical safety functions during a nuclear emergency. This tool has been in use at the IAEA for several years and has been demonstrated as a powerful tool during an emergency thru exercises with Member States such as Eskom in South Africa, CNSC in Canada and CNCAN, the Nuclear Regulatory Authority in Romania.

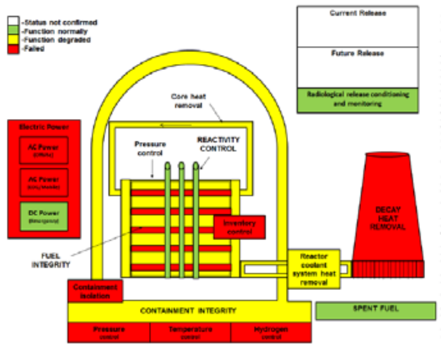


Figure 1. A snapshot of the current state for critical safety functions

2.2 France IRSN

IRSN has developed a Reactor Assessment Unit (RAU) based on 3D(diagnosis)/3P(prognosis) to provide appropriate actions during and after an emergency; (i) to limit the risk to health, safety, security and the environment, (ii) to maintain regulatory oversight of licensee's emergency response activities, and (iii) to provide support to the international response as required.

3D/3P concept has designed and applied by both IRSN for 20 years and has been adapted to other nuclear French facilities to identify the on-going accident for followings;

- to understand the actual situation (diagnosis),
- to evaluate key projected time periods and major events (prognosis),
- to evaluate source terms (diagnosis and/or prognosis) and to provide the Environmental Consequences Team.

Principles and logic of the method is a basis on safety barrier approach and are classified three barriers as shown in Table 1.

Table 1. Safety functions and the barriers

3 barriers	#1 Fuel and cladding	#2 Primary system envelope	#3 Reactor building and its extensions
Associated safety functions	• Subcriticality • Primary liquid inventory	• Removing heat from the primary system • Removing heat from primary pump seals	• Containment • Removing heat from the reactor building

IRSN's accident assessment and prognosis method aimed; (i) to predict possible accident progression for key events and timelines, (ii) to predict fission products release info based on the reactor assessment and prognosis, and (iii) to identify key info product to the EOC and federal response. The overall process shows in Figure 2.

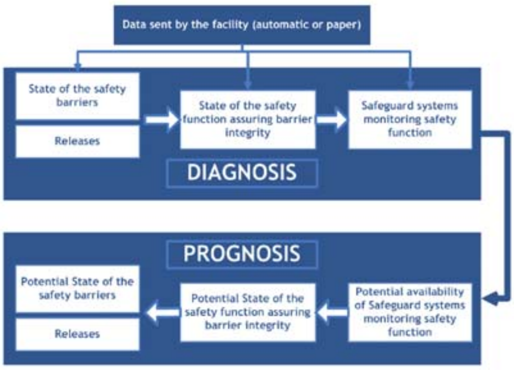
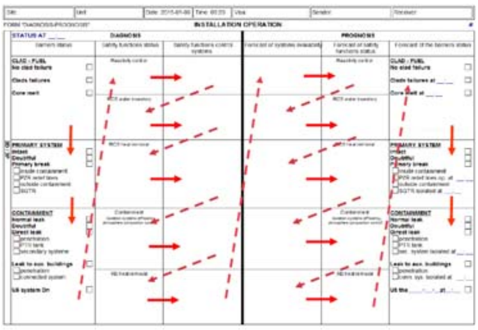


Figure 2. the overview of 3D/3P process

A grid of 3D/3P methodology and process is shown in Table 2.

Table 2. 3D/3P grid process

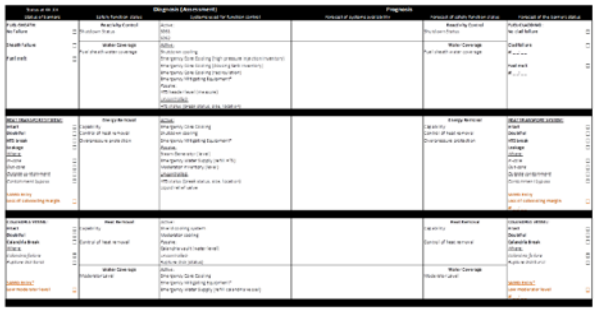


2.3 CNSC

The role of CNSC's RAT is to support MCR operators and TSC staff to take actions during and after an emergency. In this regard, the following missions are considered; (i) to maintain regulatory oversight of licensee's emergency response activities, (ii) to participate in Canada's whole-of-government response, and (iii) to provide support to the international response as required.

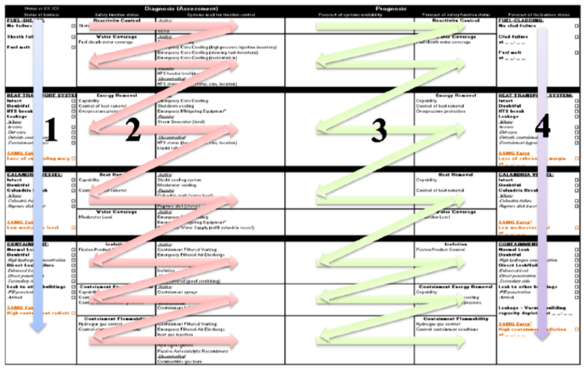
CNSC's accident assessment tool aimed at providing high-level understanding of the reactor state for emergency response. It is adapted from IRSN's 3D/3P methodology for PWRs to be applicable for CANDU reactors with 4D/4P Methodology as shown in Table 3.

Table 3. 4D/4P CANDU methodology



Likewise with IAEA RAT and IRSN 3D/3P methodology, the 4D/4P accident prognosis is also conducted diagnosis and prognosis for fission product barriers, safety function, and systems by systematic processes to identify key parameters and info required for efficient analysis. This assessment and prognosis process is called "CANDU 4D/4P Grid" as shown in Table 3.

Table 3. CANDU 4D/4P grid process



Following the prognosis, the results can used as key information to the Emergency Operation Center (EOC) in CNSC and Federal Response Organizations. As to licenses, it will be useful advised to licensee's implementation of Severe Accident Management Guidelines (SAMG).

3. APPLICATION STRATEGY

Pre-assessment and prognosis of accidents

One of the most important aspects of accident management in a nuclear and radiological emergency is the ability to promptly and adequately diagnose the progress of accident and prognose the consequences of an accident. Because of the need for preventive and mitigatory actions to be initiated promptly to be effective, accident assessment must make use of all information that is available to on-site and off-site organizations.

To evaluate the consequences of a nuclear accident occurring at a nuclear power plant throughout all phases of the emergency before, during and after a release of radioactive material, it will be considerate to adapt the 3D/3P methodology for PWRs and 4D/4P methodology for CANDU reactors because both methodologies are conducted diagnosis and prognosis for fission product barriers, safety function, and systems by step-by-step processes to identify key parameters and info required for efficient analysis.

To enhance efficiency and effectiveness in reactor assessment and plant prognoses, it will be considerate to link diagnosis and prognosis tools (e.g. 3D/3P and 4D/4P) with AtomCARE to automatically diagnose and prognosis the reactor and plant state in case of nuclear emergency aimed at providing technical support for MCR operators and TSC staff.

Figure 3. Link 3D/3P process with AtomCARE Real-time Plant Information

Post-Detail accident diagnosis and prognosis

Following pre-assessment and prognosis of accident, it could be needed to re-evaluate the expected prognoses of the accidents that can be obtained through a 3D/3P for estimation of possible consequences of severe accidents by simulation of the severe accident code (MELCOR, MAAP) and for taking the right actions for accident management.

However, since most severe accident codes require plant information to estimate possible consequences of severe accidents. In this situation, the explicit use of real-time plant information in the AtomCARE would be inherently useful in the severe accident code analysis to make predictions for the plant's behaviour as well as to eliminate the uncertainty from selection of plant parameters. The plant-specific information can be obtained at either the level of the plant systems or the level of the phenomenological parameters from AtomCARE to be employed in the utilized codes such as MELCOR and MAAP.

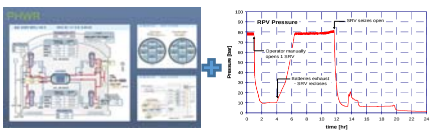


Figure 4. Link MELCOR process with AtomCARE Real-time Plant Information

3. CONCLUSIONS

KINS has developed the AtomCARE to diagnose and prognosis the reactor and plant state in case of nuclear emergency. To enhance capability of diagnosis and prognosis for AtomCARE, it will be considerate followings:

- To adapt 3D/3P methodology for PWRs and 4D/4P methodology for CANDU reactors
- To link diagnosis and prognosis tools (e.g. 3D/3P and 4D/4P) with AtomCARE to automatically diagnose and prognosis the reactor and plant state in the phase of the pre-assessment and prognosis of accidents during nuclear emergency.
- Following pre-assessment and prognosis of accident, detail accident diagnosis and prognosis processes are needed to confirm the adequacy of the expected prognoses of the accidents by simulation code (MELCOR, MAAP) so as to take the right actions for accident management.
- To use real-time plant information from AtomCARE in the SA code analysis for predictions of the plant's behaviour in such a way to link SA codes and AtomCARE.

In conclusion, IAEA, IRSN in France, CNSC in Canada have developed the Reactor Assessment Tools (RATs) for evaluating operability of critical safety functions during a nuclear emergency based on lessons learned from Fukushima Daiichi accident. These RATs are useful to adapt for performing a rapid situational evaluation with limited information available during an emergency in Korea.

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